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1 **Whole grain intakes in Irish Adults: findings from the National Adults Nutrition Survey**  
2 **(NANS)**

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24 and provided expert advice throughout. NFD and COD carried out the data analysis and wrote the  
25 first draft. BAMcN and APN contributed to the design of the study, data analysis, paper editing and  
26 review. MB contributed to data analysis and review. All authors critically reviewed the manuscript  
27 and approved the final version submitted for publication.

28

## 29    **Abstract**

30    *Purpose:* Observational studies link high whole grain intakes to reduced risk of many chronic  
31    diseases. This study quantified whole grain intakes in the Irish adult population and examined the  
32    major contributing sources. It also investigated potential dietary strategies to improve whole grain  
33    intakes.

34    *Methods:* Whole grain intakes were calculated in a nationally representative sample of 1500 Irish  
35    adults using data from the most recent national food survey, the National Adult Nutrition Survey  
36    (NANS). Food consumption was assessed, at brand level where possible, using a 4-day semi-  
37    weighed food diary with whole grain content estimated from labels on a dry matter basis.

38    *Results:* Mean daily whole grain intakes were  $27.8 \pm 29.4$  g/d, with only 19% of the population  
39    meeting the quantity specific recommendation of 48g per day. Wheat was the highest contributor to  
40    whole grain intake at 66%, followed by oats at 26%. High whole grain intakes were associated with  
41    higher dietary intakes of fibre, magnesium, potassium, phosphorus and a higher alternative  
42    Mediterranean Diet Score. Whole grain foods were most frequently eaten at breakfast time.  
43    Regression analysis revealed that consumption of an additional 10g of whole grain containing  
44    'ready to eat breakfast cereals', 'rice or pastas', or 'breads' each day would increase intake of whole  
45    grains by an extra 5g, 3.5g and 2.7g respectively.

46    *Conclusions:* This study reveals low intakes of whole grains in Irish adults. Recommending cereals,  
47    breads and grains with higher whole grain content as part of public health campaigns could improve  
48    whole grain intakes.

49

## 50    **Keywords**

51    Whole grain intakes; adults; Ireland; food surveys; intake patterns

52

## Introduction

The health implications associated with whole grain consumption have been widely documented, with previous research demonstrating that increasing whole grain intakes in the diet can result in positive health outcomes [1]. At a nutrient level, high whole grain consumption has been associated with diets rich in vitamins A, C, E, B6, fibre, folate, magnesium, potassium, phosphorus, calcium and iron [2, 3]. In terms of health, a number of meta-analyses have concluded that high whole grain intakes are associated with a reduced risk of many non-communicable diseases such as cardiovascular disease [4, 5], type 2 diabetes [6] and some cancers [7, 8]. Although, findings from intervention trials are not so convincing [1], it has been postulated that differences in study design, and methods of whole grain calculation make it difficult to compare findings [9]. Specific mechanisms behind any beneficial effect of whole grain intake remain unclear, with proposed explanations including the functional components of whole grains e.g. carotenoids, beta-glucan, inulin, phenolic acid, dietary fibre [10] and/or their nutrient profile [11]. It is also postulated that whole grains exert their benefits through actions such as reducing inflammation, improving blood lipid profile, reducing body weight, lowering blood pressure and exerting positive metabolic and hormonal effects due to phytochemicals present [5, 12, 13, 14].

With growing evidence supporting the inclusion of whole grain foods in the diet, intake patterns across and within populations worldwide are more routinely assessed and dietary recommendations increasingly mention whole grains. In certain countries such as Denmark and the US, specific quantitative intake recommendations of 75g and 48g per day have been established, whilst in other countries (Ireland, the UK and France), recommendations remain vague, and simply encourage whole grain varieties to be chosen over refined sources [15]. This may be due to the difficulties in establishing a uniform global definition of whole grain, due to issues such as the extent of processing permitted and which grains should be included in the definition [1]. Ferruzzi and colleagues proposed that the lowest amount a whole grain food should contain is 8g per 30g product (27g/100g) and based on this, the food product could be labelled as a 'whole grain food' [16], with similar thresholds endorsed recently by the Healthgrain forum ( $\geq 30$ g whole grain ingredients) [17].

Whole grain intakes in Irish children and teenagers have previously been reported using data from the National Children's Food Survey and the National Teens' Food Survey [18], with no information on the intake patterns of older age groups. The aim of the current paper is to investigate the whole grain intakes in the Irish adult population, assess the major contributing sources and to investigate potential dietary strategies to improve whole grain intakes in the Irish population.

## 86    **Methods**

### 87    *National Adult Nutrition Survey (NANS)*

88    The National Adult Nutrition Survey (NANS) is a cross-sectional food survey, completed between  
89    2008 and 2010, and conducted by the Irish Universities Nutrition Alliance (IUNA, [www.iuna.net](http://www.iuna.net)).  
90    Ethical approval was obtained from University College Cork Clinical Research Ethics Committee of  
91    the Cork Teaching Hospitals and the Human Ethics Research Committee of University College  
92    Dublin (ECM 3 (p) 4 September 2008). Written consent was obtained from all participants in  
93    accordance with the Declaration of Helsinki. A more detailed description of the survey methodology  
94    has been reported elsewhere [19]. Because the Republic of Ireland does not have a national  
95    identification system for adults, a database of names and addresses held by Data Ireland (National  
96    Postal Service) was used to randomly select persons in 20 geographical clusters across the country,  
97    selected to provide proportional representation across the urban-rural continuum. In total, 1500 adults  
98    aged 18-90 years (740 men and 760 women) took part, with a response rate of 60%. A sample of  
99    1500 free-living adults to represent a population of >4 million people participated in the dietary  
100    survey. The sample size was chosen to deliver at least 100 individuals in the least-populated age and  
101    sex subgroups. There were few exclusion criteria, other than pregnancy/lactation and inability to  
102    complete the survey because of disability. The sample was representative of the Irish population with  
103    respect to gender, age, location and social class as per the 2006 Irish census (Central Statistics Office  
104    2007).

106    Food and beverage intake was determined using a 4-day semi-weighed food diary and assessed using  
107    WISP V3.0 (Tinuviel Software, Anglesey, UK), based on data from the McCance and Widdowson's  
108    The Composition of Foods (5<sup>th</sup> and 6<sup>th</sup> editions) supplemented with Irish food codes, to calculate  
109    nutrient intakes. Each food/ beverage consumed was recorded and allocated an individual food code  
110    and brand code with the participant recording the time of eating, the eating location and self-defining  
111    each eating occasion as either a meal or a snack. The alternate Mediterranean Diet Index (aMED) was  
112    calculated per individual as a marker of diet quality [20]. Under-reporters were determined as those  
113    individuals who had a reported energy intake less than their basal metabolic rate (BMR) multiplied  
114    by PAL 1.1 [21] and removed from subsequent analysis. Supplement use was also recorded.

116    From this food and nutrient database, all whole grain foods were identified (at brand level) and a new  
117    whole grain database formed, the method for which has previously been described [18]. A whole  
118    grain food was defined as any food containing a whole grain ingredient as listed in the Healthgrain  
119    forum whole grain definition e.g. whole grain wheat, oats, rice, maize/corn, barley and rye [22]. Foods

were included in this study regardless of the whole grain content of the foods. Whole grain foods were then grouped into 1 of 7 groups for further analysis (Table 1). The total whole grain content per 100g of each food, and the source of whole grain in the food e.g. wheat, rye were also recorded. The amount of whole grain ‘actually consumed’ was then calculated by multiplying the amount of whole grain per 100g by the weight of food consumed. Following this, the dry weights of all whole grains were calculated to correct for water content as recommended by Ross and colleagues [8]. The dry weights of each whole grain ingredient were calculated by multiplying the % dry matter by the total weight of the food in 100g per day [23]. The % dry matter were obtained from McCance and Widdowson’s Cereal and cereal products supplement [24]. All data are presented on a % dry matter basis.

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### 131 *Statistical Analysis*

Statistical analyses were carried out using SPSS® for Windows™ statistical software package version 20.0 (SPSS Inc., Chicago, IL, USA). The mean and standard deviations were calculated for the daily intake of total whole grain according to sex, age group, social class and eating location for the total population and for consumers of whole grain. As the distribution of the data approximated normality [17], statistical differences within the groups were detected either using independent t-tests (gender) or by one-way analysis of variance, adjusting for age group, social class and eating location as appropriate. Bonferroni post hoc tests were conducted and where appropriate corrected at a family level for type 1 error a rate of 5%.

140

The percentage contribution of each whole grain food group made to the diet was analysed, and the main whole grain sources were identified. Simple meal pattern analysis was carried out to assess the most common meals contributing to whole grain intakes whereby the proportion of total whole grain consumed was calculated for each meal type as defined by the participants in the food diaries (i.e. % of daily whole grain consumed at breakfast, lunch, dinner, snacks). Differences in mean daily intakes of macro- and micro-nutrients for consumers versus non-consumers of whole grain were evaluated using independent samples t-test.

Further analysis was carried out to determine the percentage of Irish adults not meeting US minimum recommendations for whole grain intakes (48g/day) [25].

Multiple linear regression analysis was conducted to explore the relationship of the seven whole grain food groups that contributed the most to total whole grain intakes. This was conducted on energy adjusted mean daily whole grain intakes using a backward process which was considered the best fit for the model.

## 154 Results

155 Mean and median daily intakes of whole grain (g/day) are presented in Table 2 for Irish adults (aged  
156 18-90 years) and are presented for gender, age group, social class and eating location, for both the  
157 total population and consumers only. Over 90% of Irish adults are consumers of whole grain foods,  
158 with mean daily intakes of  $27.8 \pm 29.4$  g (total population), increasing to  $30.6 \pm 29.5$  g for consumers  
159 only. Males consumed more whole grain ( $P < 0.001$ ) in comparison to females, with mean daily intakes  
160 of  $31.6 \text{ g} \pm 35.7$  versus  $24.1 \text{ g} \pm 20.9$  for the total population and  $35.0 \text{ g} \pm 35.9$  versus  $26.3 \text{ g} \pm 20.5$  for  
161 consumers only. No intake differences were found across the age groups, however, there were  
162 significant differences observed across social class and eating locations. The highest mean intake of  
163 whole grains ( $31.1 \pm 30.0$  g/day) was identified in those individuals classed as professional/managerial  
164 which was significantly ( $P < 0.05$ ) higher than those individuals with skilled or manual jobs ( $22.7 \pm$   
165  $23.5$  g/day).

### 167 *Whole grain recommendation*

168 The percentage of Irish adults meeting the US minimum whole grain recommendation of 48g/day  
169 [25] was 19%, with little variation in compliance according to age group (Table 3).

### 171 *Grain sources and food sources of whole grain*

172 Wheat was the major grain source consumed by the Irish adult population, and accounted for 66% of  
173 all whole grain intakes. Oats were the next greatest source of whole grain (26%), while barley, rice,  
174 rye and maize made up the lesser amounts ( $< 8\%$ ) (Figure 1). Table 4 presents the food sources of  
175 whole grain, by food group and across the tertiles of intake i.e. where the lowest consumers of whole  
176 grain are presented in tertile 1 and the highest consumers in tertile 3. The major food group  
177 contributing to whole grain intake in Irish adults was 'bread and rolls' (47% contribution) followed  
178 by 'ready to eat breakfast cereals (RTEBC)' (26%) and 'other breakfast cereals' e.g. porridge (7%).  
179 Across the tertiles, those in the highest tertiles had significantly ( $P < 0.05$ ) greater intakes of all food  
180 groups except 'rice, pasta and their dishes' and 'meat products, tofu & yoghurts'.

### 183 *Food sources of whole grain at mealtimes*

184 Table 5 presents the food sources of whole grain consumed at different mealtimes and as snacks, for  
185 the Irish adult population. Breakfast was the greatest contributor of whole grain intakes, providing  
186 over 49% of the daily whole grain consumption. Of this, RTEBC and breads & rolls contributed most  
187 significantly, providing nearly 40% and 35% of whole grain intake at breakfast respectively. At lunch,

188 dinner and snacks, whole grain bread and roll products contributed most to total whole grain intakes  
189 at 80%, 58% and 44% respectively. Of note, whole grain containing sweet biscuits and related  
190 products, and savoury biscuits and related products were more likely to be consumed as snacks  
191 providing 30% and 15% of whole grain consumed at this eating occasion.

192

### 193 ***Consumers versus non-consumers of whole grain***

194 Comparing energy-adjusted nutrient intakes (% energy, mg/10MJ or µg/10MJ) across consumers  
195 and non-consumers of whole grain, Table 6 shows non-consumers to have significantly lower intakes  
196 of carbohydrate, fibre, potassium, phosphorus, magnesium and higher total fat intakes in comparison  
197 with high whole-grain consumers. The aMED was significantly higher in tertile 3 in comparison with  
198 non/lower/medium consumers of whole grain.

199

### 200 ***Proposed strategies to increase intakes of whole grains in the Irish population***

201 Table 7 presents the impact of increasing whole grain intakes across food groups. This analysis shows  
202 that by increasing consumption of whole-grain food groups has a varied impact on overall intakes.  
203 For example, if an individual was to increase their intake of RTEBC by 10g per day, their daily whole  
204 grain intake would increase by nearly 5.4g. In contrast, a 10g daily increase in intakes of whole grain  
205 containing bread and rolls or other breakfast cereals would increase daily whole grain intakes by  
206 2.75g and 0.14g respectively. An additional 10g per day of savoury biscuits, crackers and popcorn  
207 would increase daily whole grain intake by 7.5g.

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## 223 Discussion

224 The current paper describes whole grain intakes in Irish adults using data from the NANS study. For  
225 the total population, the mean intake of whole grains was 27.8 g per day (median 20g/day), with over  
226 91% of Irish adults identified as consumers of whole grains. Whole grain intakes differed in terms of  
227 gender and social class, with males and those from higher social classes having higher intakes. In  
228 comparison with the US quantity specific whole grain intake recommendation of 48g/day [25], only  
229 19% of the Irish adult population met this minimum guideline. Approximately 50% of all whole  
230 grain was consumed by Irish adults at breakfast, double the amount consumed at lunch, the second  
231 most frequent whole grain eating occasion, with a reliance on wheat sources. Regression analysis  
232 demonstrated that increased intakes of whole grain containing foods such as RTEBCs, rice and pastas  
233 and bread by as little as 10g per day, could potentially enhance actual whole grain intakes in Irish  
234 adults.

236 Dietary whole grain intakes have previously been described for Irish children and teenagers with  
237 mean daily intakes of 18.5 and 23.2 g/d respectively and with over 90% of children aged 5-12 years  
238 and over 86% of teenagers aged 13-17 years consuming whole grains (intakes for consumers only of  
239 20.5 and 16.9 g/day respectively) [18]. Ready-to-eat breakfast cereals made the greatest contribution  
240 to whole grain intakes in these Irish children and teens (44-59% of whole grain), followed by bread  
241 and rolls (14-26% of whole grain) [18]. The reverse order was observed in the present study of Irish  
242 adults, perhaps suggesting lowered consumption of whole grain containing breakfast cereals in adults  
243 and a greater reliance on breads and rolls for whole grain intake. In all studies, wheat was the major  
244 contributing grain, followed by oats. Our intake patterns (median daily intake 20g per day) are in line  
245 with those reported from other countries [3, 26, 28, 29]. Recent data from the UK also reported a  
246 median daily intake of 20g for whole grains in adults, with whole-grain breads and ready to eat  
247 breakfast cereals as primary and secondary sources and wheat the main grain [26]. However, unlike  
248 the current study which reported absolute intakes, energy-adjusted whole grain intakes appeared to  
249 increase with age in the UK population, with females having higher whole grain intakes [26].  
250 Australian consumption is reported as 21g/day for adults [28], with comparable values estimated for  
251 US adults aged 19-50y in 2010 as 0.72 oz equivalents (approximately <20g/d) [29]. In contrast, very  
252 low consumption levels are reported for France (mean daily intake of 4.7g per day [27] and Italy  
253 (mean daily intake of 3.7 g per day [30]). The highest daily intakes are reported for Denmark where  
254 a successful health campaign increased whole grains by 72% from an average of 32g/d in 2000-2004  
255 to 55g/d in 2011-2012 [31]. Similar efforts are needed to boost whole grain intakes by Irish adults.

257 Differences between consumers and non-consumers of whole grains were investigated in this Irish  
258 population, with non-consumers having significantly lower energy-adjusted intakes of dietary fibre,  
259 potassium, phosphorus, magnesium and iodine, and higher total fat and MUFA (% energy) compared  
260 with consumers of whole grain. In the UK, higher intakes of whole grains were associated with  
261 significantly higher intakes of dietary fibre, iron, calcium, vitamin E, potassium, phosphorus,  
262 magnesium, thiamin, vitamin B12 and vitamin D [32]. These findings are in line with studies which  
263 report a healthier eating pattern in those with higher intakes of whole grains [2, 27, 32, 33]. For  
264 example, in a subsample of the Scandinavian cohort 'HELGA', the intake of whole grains was  
265 directly associated with intakes of vegetables, fruits, dairy products, fish and shellfish and inversely  
266 associated with intakes of white bread, red meat and cakes and biscuits [33]. Similarly, in Irish adults,  
267 high whole grain intakes were associated with a higher aMed Score which indicates greater  
268 compliance to a Mediterranean style diet and may be viewed a marker of higher dietary quality.

270 In the current study, we completed a simple investigation of strategies to understand patterns of whole  
271 grain intake and to increase their consumption in the Irish population as low whole grain intakes were  
272 observed. The overwhelming majority of whole grain containing foods were consumed at breakfast  
273 suggesting opportunities for encouraging whole grain options at other eating occasions, particularly  
274 lunch and dinner. Wheat was the major grain form consumed, implying potential for other grain  
275 sources, particularly oats. Further, using regression analysis, it became apparent that simply  
276 increasing the quantities of whole grain foods as currently consumed resulted in variable increases in  
277 daily whole grain intake. For example, consuming an additional 10g of whole-grain containing  
278 RTEBC per day yielded an additional 5.5g whole grain. While 10g extra of whole grain containing  
279 'rice, pasta and their dishes' yielded an extra 3.5g whole grain, 10g more of 'bread and rolls' provided  
280 an extra 2.75g. Hence simple substitution of food choices has the potential to enhance population  
281 whole grain intakes albeit that any such substitution will also be impacted by portion size and amounts  
282 usually consumed per serving. We note that the single greatest impact was by consuming 10g extra  
283 of the group 'savory biscuits, crackers and popcorn' (7.5g additional whole grain), a food group  
284 likely to contain levels of nutrients deemed less acceptable for public health e.g. fat, sugar or salt but  
285 typically associated with smaller portion sizes. Overall an opportunity exists for the food industry to  
286 develop more whole grain-rich foods with acceptable sensory qualities, yet without concomitant high  
287 salt and sugar contents. Use of a universally agreed labelling system for whole grain containing foods,  
288 as suggested by the Healthgrain forum [17] may encourage development of such foods while also  
289 highlighting to public health advocates and consumers options which are more healthful.

290

291 Currently there are no specific whole grain recommendations set in Ireland, or in the UK, making it  
292 is difficult to place in context current intake patterns and the impact of any strategies to increase  
293 whole grain intakes. In the absence of such national recommendations, dietary whole grain intakes  
294 were compared to the US recommendation of 48g/day [25], with only 19% of individuals in this Irish  
295 adult cohort each achieving this guideline. In additional analysis, we also used an alternative approach  
296 to assess mean population compliance [34]. Such an approach acknowledges the distribution of intake  
297 of any nutrient or ingredient in a population and accepts that dietary guidelines are targeted at  
298 populations, rather than individuals. Hence, it is not necessary for all individuals in a population to  
299 each achieve this goal, rather that mean population intakes should satisfy the recommendation [34].  
300 However, using this approach, there remained poor population compliance with the whole grain  
301 recommendation, with less than half (47%) of the entire NANS study population having an overall  
302 mean intake of 48g/day. Irrespective of method used, such low intakes, suggests a need for more  
303 specific whole grain recommendations which reflect the importance of having a diet high in whole  
304 grains for additional benefits above and beyond dietary fibre, as discussed by Seal and colleagues  
305 [15]. Observational studies consistently link high whole grain intakes and a reduced risk of CVD [4],  
306 type 2 diabetes [5,6], metabolic syndrome [5] and a number of different cancers [8]. It is likely that  
307 more specific whole grain recommendations would aid successful public health campaigns to  
308 improve whole grain intakes similar to that of Denmark [31]. In the US, a health claim pertaining to  
309 whole grain intakes is permitted based on the strength of the evidence to support the benefits of a diet  
310 high in whole grains, however, no such health claim is currently approved by EFSA [15]. It is likely  
311 that a more specific whole grain recommendation would make it easier to transfer the health message  
312 across to consumers due to clearer labelling regarding whole grains on food products. The results of  
313 this current study and from previous Irish cohorts in Irish children and teens, highlights the need for  
314 a more specific whole grain recommendation and targeted public health campaigns similar to  
315 Denmark [17,31].

316

317 This study has some noteworthy strengths such as the large sample size which is representative of the  
318 Irish population. Furthermore, dietary data was collected using a 4-day semi-weighed food diary  
319 which accounts for potential intra-variation in dietary habits within participants. Furthermore, where  
320 possible, food packaging was obtained to ensure a higher level of accuracy regarding the dietary data  
321 and the ability to ascertain whole grain composition at a brand level where feasible. The current  
322 analysis was conducted following the removal of under-reporters which ensures absence of mis-  
323 reporting in the dataset. A limitation of the current study is the lack of a biomarker for whole grain  
324 intake to validate the dietary data collected. Alkylresorcinols have been identified as valid biomarkers

325 of whole-grain wheat and rye intake and may be useful for future studies investigating whole grain  
326 intake [35].

327

328 In conclusion, this study is the first to report whole grain intakes in Irish adults using data from the  
329 national food survey, NANS. We reported low whole grain intakes in Irish adults similar to Irish  
330 children and teens and other countries such as the UK and France. We also show how the selection  
331 of whole-grain containing RTEC, breads and pastas/rice has the potential to enhance daily intakes.  
332 These findings support the argument for the development of a more specific whole grain  
333 recommendation in Ireland and universally agreed labelling in light of the proposed health benefits  
334 for a diet high in whole grains. Public health campaigns are warranted to try and improve whole grain  
335 intakes in the Irish population across all age groups. Future work should also investigate the proposed  
336 metabolic health benefits of consuming a diet high in whole grains in this population.

337

338

#### 339 **Ethical Standards**

340 This study was approved by the University College Cork Clinical Research Ethics Committee of the  
341 Cork Teaching Hospitals and the Human Ethics Research Committee of University College Dublin  
342 (ECM 3 (p) 4 September 2008) and performed in accordance with the ethical standards laid down in  
343 the 1964 Declaration of Helsinki and its later amendments. All persons gave their informed consent.

344

#### 345 **Conflict of Interest**

346 APN and MJG have previously received unrestricted research funding from Cereal Partners  
347 Worldwide, with no influence in the current analysis or study. There are no other conflicts of interest  
348 to declare.

349

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442 **List of Figures**

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444 **Fig. 1** Contribution (%) of food group categories to mean daily whole grain intakes in whole  
445 grain consumers

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**Table 1** Description of the foods included in each of the 7 whole grain food groups

| Food Group                               | Foods included  |
|--|---|
| Rice, pasta and their dishes             | Brown and whole grain rice, wholemeal pasta, risottos, pasta bakes, lasagne, pasta and rice salads  |
| Breads and rolls <sup>a</sup>            | Wholemeal, brown, brown soda and granary breads and rolls. Other whole grain breads including scones, pitta breads and bread mix.         |
| RTEBC <sup>b</sup>                       | All ready to eat breakfast cereals  |
| Other breakfast cereals                  | Porridge and cooked breakfast cereals   |
| Sweet biscuits, cereal bars and desserts | Plain and chocolate digestive biscuits, oat based biscuits, chewy, crunchy and baked cereal bars, flapjacks, cheesecake and biscuit cake. |
| Savoury biscuits, crackers and popcorn   | Oatcakes, crackers, shop bought, microwaveable, toffee, butter and sweet popcorn  |
| Meat products, tofu and yoghurts         | White and black pudding, tofu products, cereal based yoghurts   |

<sup>a</sup>All breads and rolls were cross-checked at brand level and with manufacturers to ensure ingredients were whole grain containing.

<sup>b</sup>RTEBC, ready to eat breakfast cereals

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**Table 2** Descriptive analysis of whole grain intake (g/d) for Irish adults (total population and whole grain consumers only)

|                                 | Total Population (n = 1051) |      |                     |        |      |       |     | Consumers Only (n = 957; 91.1%) |      |                     |        |      |       |     |
|---------------------------------|-----------------------------|------|---------------------|--------|------|-------|-----|---------------------------------|------|---------------------|--------|------|-------|-----|
|                                 | n                           | %    | Mean                | Median | SD   | P97.5 | P   | n                               | %    | Mean                | Median | SD   | P97.5 | P   |
| Total Population                | 1051                        | 100  | 27.8                | 20.0   | 29.4 | 102.7 |     | 957                             | 91.1 | 30.6                | 22.5   | 29.5 | 108.8 |     |
| <b>Sex</b>                      |                             |      |                     |        |      |       |     |                                 |      |                     |        |      |       |     |
| Male                            | 523                         | 49.8 | 31.6                | 18.5   | 35.7 | 130.4 | *** | 473                             | 49.4 | 35.0                | 23.8   | 35.9 | 142.1 | *** |
| Female                          | 528                         | 50.2 | 24.1                | 20.4   | 20.9 | 76.1  |     | 484                             | 50.6 | 26.3                | 21.6   | 20.5 | 78.0  |     |
| <b>Age</b>                      |                             |      |                     |        |      |       |     |                                 |      |                     |        |      |       |     |
| Age group 1 <sup>†</sup>        | 377                         | 35.9 | 29.5                | 21.0   | 33.2 | 118.7 | NS  | 335                             | 35.0 | 33.2                | 23.7   | 33.4 | 120.3 | NS  |
| Age group 2 <sup>†</sup>        | 308                         | 29.3 | 27.5                | 20.6   | 27.7 | 96.6  |     | 280                             | 29.3 | 30.3                | 23.8   | 27.6 | 97.2  |     |
| Age group 3 <sup>†</sup>        | 204                         | 19.4 | 27.2                | 20.1   | 27.0 | 85.3  |     | 191                             | 20.0 | 29.1                | 21.4   | 27.0 | 86.4  |     |
| Age group 4 <sup>†</sup>        | 162                         | 15.4 | 25.4                | 15.8   | 26.0 | 94.3  |     | 151                             | 15.8 | 27.2                | 19.7   | 26.0 | 96.3  |     |
| <b>Social Class<sup>v</sup></b> |                             |      |                     |        |      |       |     |                                 |      |                     |        |      |       |     |
| Professional /managerial        | 484                         | 46.1 | 31.1 <sup>a</sup>   | 22.9   | 30.0 | 109.3 | *   | 450                             | 47.0 | 33.5 <sup>a</sup>   | 24.6   | 29.9 | 110.5 | *   |
| Non-manual                      | 183                         | 17.4 | 25.6 <sup>a,b</sup> | 16.4   | 25.3 | 90.3  |     | 169                             | 17.7 | 27.7 <sup>a,b</sup> | 21.0   | 25.2 | 90.7  |     |
| Skilled manual                  | 142                         | 13.5 | 22.7 <sup>b</sup>   | 15.3   | 23.5 | 84.3  |     | 125                             | 13.1 | 25.8 <sup>b</sup>   | 20.9   | 23.4 | 86.8  |     |
| Semi-skilled and unskilled      | 205                         | 19.5 | 27.0 <sup>a,b</sup> | 15.5   | 34.7 | 121.6 |     | 178                             | 18.6 | 31.1 <sup>a,b</sup> | 20.1   | 35.5 | 132.3 |     |
| <b>Eating Location</b>          |                             |      |                     |        |      |       |     |                                 |      |                     |        |      |       |     |
| Home                            | 1050                        | 99.9 | 24.6 <sup>b</sup>   | 16.5   | 27.7 | 96.2  | *** | 956                             | 99.9 | 27.0 <sup>b</sup>   | 19.1   | 27.8 | 98.1  | *** |
| Other Home                      | 306                         | 29.1 | 1.7 <sup>a</sup>    | 0.0    | 4.9  | 16.2  |     | 285                             | 29.8 | 1.8 <sup>a</sup>    | 0      | 5.1  | 16.6  |     |
| Outside Home                    | 862                         | 82.0 | 3.4 <sup>a</sup>    | 0.0    | 8.0  | 25.8  |     | 784                             | 81.9 | 3.7 <sup>a</sup>    | 0      | 8.3  | 28.0  |     |

<sup>abc</sup>Values with unlike superscript letters denote significant differences between mean daily intakes of whole grain (ANOVA with Scheffé post hoc tests): \*P<0.05, \*\*P<0.01,

\*\*\*P<0.001, NS: not significant (P≥0.05). <sup>†</sup>Age group 1: 18-35 years, Age group 2: 36-50 years, Age group 3: 51-64 years, Age group 4: 65-90 years. <sup>v</sup>Excluding data for 37 students (missing data)

**Table 3.** Percentage of Irish adults meeting US whole grain recommendations of 48g/day [25]

| Total population <i>n</i> 1051 |                  |
|--------------------------------|------------------|
|                                | (%) <sup>a</sup> |
| All adults (18-90 yrs)         | 19.3             |
| Adults (18-35 yrs)             | 21.0             |
| Adults (36 – 50 yrs)           | 18.8             |
| Adults (51 – 64 yrs)           | 16.7             |
| Adults (65 – 90 yrs)           | 19.8             |

<sup>a</sup> refers to the percentage of individuals in the Irish population who met the dietary recommendations for minimal whole grains of 48g/day [25].

**Table 4** Intake (g/10MJ/day) and contribution (%) of food groups to mean daily whole grain intakes in an Irish adult population across tertiles of intake in whole grain consumers

|  | Tertiles of mean daily whole grain intakes (g/10MJ/d) |      |      |       |           |                  |      |       |           |                    |      |       |           |                     |       |      |     |
|--|---|------|------|-------|-----------|------------------|------|-------|-----------|--------------------|------|-------|-----------|---------------------|-------|------|-----|
|  | Whole grain consumers                                 |      |      |       | Tertile 1 |                  |      |       | Tertile 2 |                    |      |       | Tertile 3 |                     |       |      | P   |
|  |   |      |      |       | n=319     |                  |      |       | n=319     |                    |      |       | n=319     |                     |       |      |     |
|  | n=957   |      |      |       | n=319     |                  |      |       | n=319     |                    |      |       | n=319     |                     |       |      |     |
| %Cons                                  | Mean  | SD   | %Ctr | %Cons | Mean      | SD               | %Ctr | %Cons | Mean      | SD                 | %Ctr | %Cons | Mean      | SD                  | % Ctr |      |     |
| Rice, pasta & their dishes             | 6.6   | 17.9 | 11.3 | 2.3   | 0.9       | 6.8              | 4.9  | 0.5   | 4.4       | 12.8               | 6.8  | 2.1   | 14.4      | 20.1                | 11.8  | 4.4  | NS  |
| Bread & rolls                          | 76.1  | 21.1 | 20.8 | 46.6  | 54.9      | 6.9 <sup>a</sup> | 5.0  | 40.9  | 83.7      | 17.5 <sup>b</sup>  | 12.3 | 52.7  | 89.7      | 33.1 <sup>c</sup>   | 25.8  | 46.4 | *** |
| Ready to eat breakfast cereals         | 46.4  | 22.8 | 18.4 | 25.6  | 16.9      | 6.6 <sup>a</sup> | 4.3  | 11.6  | 49.2      | 16.4 <sup>b</sup>  | 12.1 | 28.4  | 73.0      | 30.9 <sup>c</sup>   | 19.7  | 36.8 | *** |
| Other breakfast cereals                | 32.5  | 5.2  | 12.7 | 7.4   | 31.7      | 2.1 <sup>a</sup> | 1.3  | 14.2  | 37.0      | 2.9 <sup>a,b</sup> | 5.2  | 3.8   | 28.8      | 11.7 <sup>b</sup>   | 21.3  | 4.3  | *** |
| Sweet biscuits, cereal bars & desserts | 33.6  | 3.3  | 4.5  | 6.6   | 31.7      | 2.4              | 2.8  | 13.3  | 32.3      | 2.9                | 3.2  | 3.9   | 37.0      | 4.3                 | 6.3   | 2.6  | *   |
| Savoury biscuits, crackers & popcorn   | 15.8  | 11.9 | 10.7 | 6.4   | 9.4       | 6.1 <sup>a</sup> | 4.3  | 6.5   | 17.6      | 13.4 <sup>b</sup>  | 11.3 | 8.1   | 20.4      | 13.4 <sup>b,c</sup> | 11.3  | 4.6  | *   |
| Meat products, tofu & yoghurts         | 15.9  | 2.7  | 2.2  | 5.0   | 21.3      | 2.9              | 2.3  | 13.1  | 11.0      | 2.4                | 1.7  | 1.2   | 15.4      | 2.7                 | 2.4   | 0.9  | NS  |

% Cons - % consumers of each whole grain food group; % Ctr -% contribution of food groups to whole grain intakes within each tertile

<sup>abc</sup> Values with unlike superscript letters denote significant differences between the mean values of whole grain intake across the tertiles of whole grain intake (adjusted for gender)

(ANCOVA with Bonferroni correction): \* P<0.05; \*\* P<0.01; \*\*\* P<0.001; NS, P≥0.05

**Table 5** Patterns of intake (%) of all whole grain and of whole grain containing food groups as consumed at meals and snacks

|  | Breakfast | Lunch | Dinner | Snacks |
|--|-----------|-------|--------|--------|
| All sources of whole grain               | 49.5      | 22.7  | 10.3   | 17.3   |
| <i>Of which</i>                          |           |       |        |        |
| Rice, pasta and their dishes             | 0.0       | 2.2   | 11.7   | 0.0    |
| Bread and rolls                          | 35.5      | 79.6  | 58.0   | 44.2   |
| RTEBC                                    | 39.8      | 1.1   | 0.8    | 8.1    |
| Other breakfast cereals                  | 18.0      | 0.1   | 0.1    | 1.3    |
| Sweet biscuits, cereal bars and desserts | 2.0       | 7.3   | 16.2   | 29.5   |
| Savoury biscuits, crackers and popcorn   | 1.2       | 5.4   | 6.0    | 15.3   |
| Meat, tofu and yoghurts                  | 3.3       | 4.5   | 7.1    | 1.7    |

**Table 6** Mean energy and nutrient intakes for non-consumers and across the tertiles of whole grain intake in Irish adults

|                          | Non-consumers<br>(n=94) |        | Tertile 1 (n=319)   |       | Tertile 2 (n=319)   |       | Tertile 3 (n=319)   |       | P value |
|--------------------------|-------------------------|--------|---------------------|-------|---------------------|-------|---------------------|-------|---------|
|                          | Mean                    | SD     | Mean                | SD    | Mean                | SD    | Mean                | SD    |         |
| Energy (MJ)              | 8.9 <sup>a</sup>        | 2.3    | 9.2 <sup>a</sup>    | 2.7   | 9.0 <sup>a</sup>    | 2.4   | 10.1 <sup>b</sup>   | 2.7   | ***     |
| Protein (% energy)       | 15.7                    | 3.9    | 16.3                | 3.3   | 16.4                | 3.2   | 16.9                | 3.5   | NS      |
| Carbohydrate (% energy)  | 40.2 <sup>a</sup>       | 7.7    | 41.8 <sup>ad</sup>  | 6.8   | 42.6 <sup>bd</sup>  | 6.9   | 44.6 <sup>d</sup>   | 6.1   | ***     |
| Total sugars (% energy)  | 15.4                    | 6.4    | 17                  | 6.2   | 17.2                | 5.8   | 17.4                | 4.9   | NS      |
| Fat (% energy)           | 35.7 <sup>a</sup>       | 7      | 35.0 <sup>a</sup>   | 6.1   | 34.0 <sup>ab</sup>  | 6.4   | 33.2 <sup>b</sup>   | 5.9   | **      |
| Saturated fat (% energy) | 13.7                    | 4.3    | 13.9                | 3.3   | 13.4                | 3.4   | 13                  | 3.2   | NS      |
| MUFA (% energy)          | 13.5 <sup>a</sup>       | 3      | 12.8 <sup>a</sup>   | 2.6   | 12.2 <sup>b</sup>   | 2.7   | 12.0 <sup>b</sup>   | 2.5   | ***     |
| PUFA (% energy)          | 6                       | 2.3    | 6                   | 2.3   | 6.2                 | 2.5   | 6                   | 2.1   | NS      |
| Dietary fibre (g/10MJ)   | 16.5 <sup>a</sup>       | 6.3    | 19.4 <sup>b</sup>   | 6.5   | 23.4 <sup>c</sup>   | 7.2   | 26.9 <sup>d</sup>   | 7.2   | ***     |
| Sodium (mg/10MJ)         | 2892.9                  | 616.2  | 2942.4              | 675.9 | 2914.5              | 653.3 | 2913.5              | 598.3 | NS      |
| Iron (mg/10MJ)           | 16.4                    | 21.8   | 17.2                | 22.2  | 15.7                | 16.3  | 19.8                | 25.1  | NS      |
| Calcium (mg/10MJ)        | 1062.8                  | 574    | 1071.4              | 406.5 | 1161                | 453.8 | 1163.6              | 402.7 | NS      |
| Magnesium (mg/10MJ)      | 295.8 <sup>a</sup>      | 106.3  | 316.9 <sup>a</sup>  | 115.6 | 349.2 <sup>b</sup>  | 83.8  | 382.5 <sup>c</sup>  | 82    | ***     |
| Potassium (mg/10MJ)      | 3478.7 <sup>ab</sup>    | 1467.7 | 3444.7 <sup>b</sup> | 741.1 | 3666.1 <sup>a</sup> | 713.8 | 3732.3 <sup>a</sup> | 817   | **      |
| Phosphorus (mg/10MJ)     | 1453.3 <sup>a</sup>     | 276.9  | 1548.3 <sup>b</sup> | 308   | 1648.4 <sup>c</sup> | 302.4 | 1723.6 <sup>d</sup> | 295.1 | ***     |
| Iodine (µg/10MJ)         | 160.5 <sup>a</sup>      | 96.9   | 165.7 <sup>a</sup>  | 83.5  | 178.8 <sup>ab</sup> | 86.4  | 189.3 <sup>b</sup>  | 81.5  | ***     |
| Vitamin D (µg/10MJ)      | 4.1                     | 5.5    | 5.0                 | 6.0   | 5.8                 | 7.5   | 6.2                 | 9.3   | NS      |
| Thiamin (mg/10MJ)        | 2.3                     | 4.3    | 3.8                 | 10.9  | 3.3                 | 8.3   | 3.9                 | 10.4  | NS      |
| Riboflavin (mg/10MJ)     | 2.6                     | 4      | 3.7                 | 10    | 3.8                 | 8.9   | 4.1                 | 9.7   | NS      |
| Niacin (mg/10MJ)         | 32.1                    | 31.6   | 30.7                | 15.9  | 33.6                | 41.3  | 35                  | 19.5  | NS      |
| Vitamin B6 (mg/10MJ)     | 3.7                     | 4.2    | 4.5                 | 8.5   | 4.8                 | 9.7   | 5.1                 | 10.1  | NS      |
| Vitamin B12 (µg /10MJ)   | 6.7                     | 5.8    | 9.3                 | 23.9  | 11.3                | 69.5  | 8.2                 | 11.4  | NS      |
| Folate (µg/10MJ)         | 354.2 <sup>a</sup>      | 184.8  | 393.3 <sup>a</sup>  | 201.3 | 425.0 <sup>ac</sup> | 206.9 | 461.9 <sup>bc</sup> | 207.0 | ***     |
| aMED                     | 2.0 <sup>a</sup>        | 1.1    | 2.5 <sup>b</sup>    | 1.3   | 3.4 <sup>c</sup>    | 1.6   | 3.9 <sup>d</sup>    | 1.5   | ***     |

aMED, alternative Mediterranean diet score. \* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ , NS, not significant ( $P \geq 0.05$ ). <sup>abc</sup> Values with unlike superscript letters denote significant differences across the tertiles of whole grain intake (adjusted for gender) (ANCOVA with Bonferroni correction)

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**Table 7** Associations (unstandardised coefficients) of whole grain intake (g/10MJ/d) to predict the importance of whole grain food groups to increase whole grain intakes

| Whole grain food group                 | $\beta$ | SE    | P      |
|--|---------|-------|--------|
| Savoury biscuits, crackers & popcorn   | 0.755   | 0.058 | <0.001 |
| RTEBC                                  | 0.549   | 0.017 | <0.001 |
| Rice, pasta & their dishes             | 0.352   | 0.030 | <0.001 |
| Bread & rolls                          | 0.275   | 0.007 | <0.001 |
| Sweet biscuits, cereal bars & desserts | 0.166   | 0.032 | <0.001 |
| Other breakfast cereals                | 0.014   | 0.005 | 0.002  |

Note: The unstandardised coefficient for whole grain ready-to-eat breakfast cereals (RTEBC) is 0.549 meaning that for each 1g increase, there would be an increase in whole grain consumption of 0.549. Therefore, if an individual was to add 10g of a RTEBC to the daily diet, the potential impact would be an increase of 5.4g in daily whole grain intakes.